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EVALUATION OF A REMOTE TONE SIGNALING CONTROL/MONITOR SYSTEM AS--ETC(U)
JAN 79 J R BRANSTETTER

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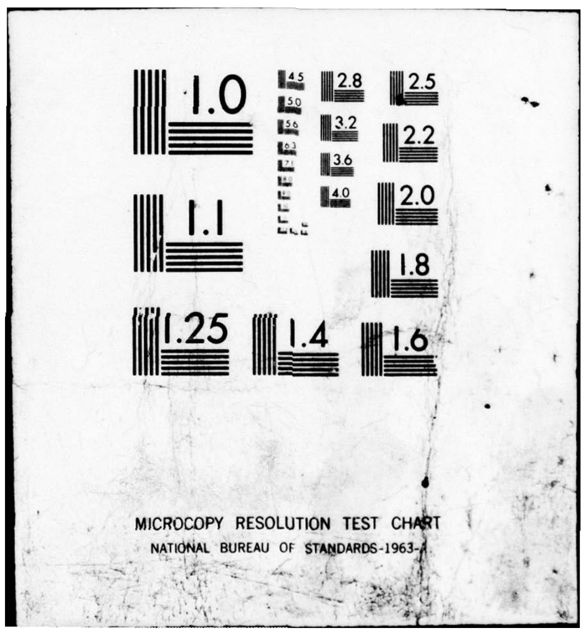
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REPORT NO. FAA-RD-78-149

LEVEL II

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EVALUATION OF A REMOTE TONE SIGNALING CONTROL/MONITOR SYSTEM AS LIGHTNING/TRANSIENT PROTECTION FOR SOLID STATE INSTRUMENT LANDING SYSTEMS

James R. Branstetter

JANUARY 1979

FINAL REPORT

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16. Abstract

A new technique in remote control and monitoring of a solid-state instrument landing system (ILS) was evaluated at the National Aviation Facilities Experimental Center (NAFEC) intended as a solution to problems caused by lightning and transients on phone lines and buried cables. The findings show the system effectively reduces or eliminates false transmitter cycling, erroneous status indications, and damage to the ILS equipment.

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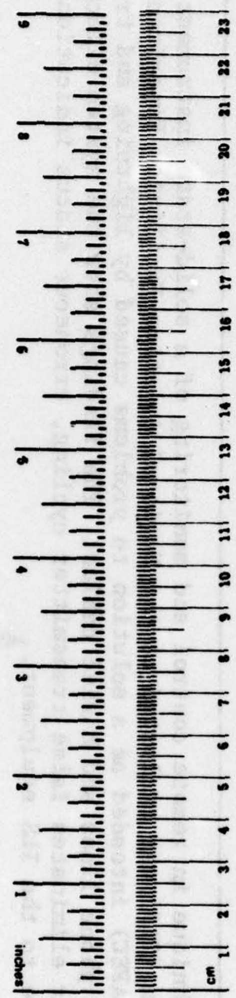
METRIC CONVERSION FACTORS

Approximate Conversions to Metric Measures

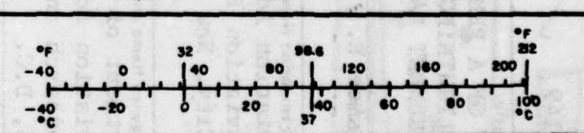
Symbol	When You Know	Multiply by	To Find	Symbol
		LENGTH		
in	inches	*2.5	centimeters	cm
ft	feet	30	centimeters	cm
yd	yards	0.9	meters	m
mi	miles	1.6	kilometers	km
		AREA		
in^2	square inches	6.5	square centimeters	cm^2
ft^2	square feet	0.09	square meters	m^2
yd^2	square yards	0.8	square meters	m^2
mi^2	square miles	2.6	square kilometers	km^2
	acres	0.4	hectares	ha
		MASS (weight)		
oz	ounces	28	grams	g
lb	pounds	0.45	kilograms	kg
	short tons (2000 lb)	0.9	tonnes	t
		VOLUME		
tsp	teaspoons	5	milliliters	ml
Tbsp	tablespoons	15	milliliters	ml
fl oz	fluid ounces	30	milliliters	ml
c	cups	0.24	liters	l
pt	pints	0.47	liters	l
qt	quarts	0.95	liters	l
gal	gallons	3.8	liters	l
ft^3	cubic feet	0.03	cubic meters	m^3
yd^3	cubic yards	0.76	cubic meters	m^3
		TEMPERATURE (exact)		
°F	Fahrenheit temperature	5/9 (after subtracting 32)	Celsius temperature	°C

*1 in ≡ 2.54 (exactly). For other exact conversions and more detailed tables, see NBS Misc. Publ. 286, Units of Weights and Measures, Price $2.25, SD Catalog No. C13.10:286.



Approximate Conversions from Metric Measures

Symbol	When You Know	Multiply by	To Find	Symbol
		LENGTH		
mm	millimeters	0.04	inches	in
cm	centimeters	0.4	inches	in
m	meters	3.3	feet	ft
m	meters	1.1	yards	yd
km	kilometers	0.6	miles	mi
		AREA		
cm^2	square centimeters	0.16	square inches	in^2
m^2	square meters	1.2	square yards	yd^2
km^2	square kilometers	0.4	square miles	mi^2
ha	hectares (10,000 m^2)	2.5	acres	
		MASS (weight)		
g	grams	0.035	ounces	oz
kg	kilograms	2.2	pounds	lb
t	tonnes (1000 kg)	1.1	short tons	
		VOLUME		
ml	milliliters	0.03	fluid ounces	fl oz
l	liters	2.1	pints	pt
l	liters	1.06	quarts	qt
l	liters	0.26	gallons	gal
m^3	cubic meters	35	cubic feet	ft^3
m^3	cubic meters	1.3	cubic yards	yd^3
		TEMPERATURE (exact)		
°C	Celsius temperature	9/5 (then add 32)	Fahrenheit temperature	°F



PERFACE

The author wishes to thank the Eastern Region maintenance personnel of the Atlantic City Sector, AFSFO-823.6, who were most helpful and cooperative during the course of this project.

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INTRODUCTION

PURPOSE.

This project was established to evaluate a remote control and monitoring system for solid-state instrument landing systems (ILS) designed to reduce equipment damage, false transmitter cycling, and erroneous status indications caused by lightning and control line transients.

BACKGROUND.

The remote status and control lines interconnecting ILS field units with associated monitor and control stations located in the control tower are highly susceptible to lightning and line transients. The attendant undesirable effects have, on numerous occasions, resulted in extensive damage to ILS circuitry and caused many nuisance transfers and shutdowns of operating equipment. During a lightning strike, several thousand volts can be induced on control and power lines located in the vicinity of the strike. Previous vacuum-tube equipment was generally capable of dissipating the high voltages without damage to operating circuits, since it was designed for relatively high B+ voltages in normal operation. In solid-state ILS equipment, the circuity operates at voltages considerably less than its tube-type predecessor and thus has a lesser margin of tolerance for any transient voltages.

At the present time, the lines used with most ILS systems in the field carry direct current (d.c.) levels to effect signaling and control. This type of operation includes the use of unbalanced lines which greatly increases their susceptibility to damaging transients. Additionally, the large number of lines used to interconnect the system, 100 individual wires for the Texas Instruments-type Federal Aviation Administration (FAA) Mark III ILS (figure 1), may have contributed to the probability of incurring circuit damage or causing transfers and shutdowns.

Previous work in the lightning/transient protection area for the FAA had been conducted by Georgia Institute of Technology. Their effort was limited to developing designs for connecting protective devices across existing lines. Results of their studies are found in references 1 and 2.

Purdue University was awarded a contract, DOT-FA74WA-3518, in June 1974, to perform a study and recommend an alternate solution to the existing problem. In their first report (reference 3), previous equipment failures and operational upsets were investigated and analyzed. The report also presented reliable signal processing and line protection techniques and described a proposed prototype to be built and installed at the National Aviation Facilities Experimental Center (NAFEC). The new system would employ a <u>single pair</u> of wires carrying audio tones in lieu of the existing multipair d.c. cables running to each site. This was expected to provide superior protection from transient interference.

As an added benefit, a substantial savings in the cost of leasing telephone company (telco) services and/or laying of buried cables can be realized.

During the summer of 1975, a rudimentary tone-signaling system was connected to the category (CAT) II ILS localizer, inner marker, and far-field monitor serving runway 31. The system was operated for several months affording NAFEC and maintenance personnel the opportunity to obtain experience in the new techniques. A second report (reference 4) gave a technical description of the first generation (prototype) equipment and commented on insight gained during the trial period. The report delineated plans for installing a complete tone-signaling system utilizing the CAT III ILS serving runway 13. This system would connect all of the ILS components: the tower status and control stations, the localizer, the glide slope, the inner, middle, and outer markers, and the far-field monitor. The second generation equipment was designed, constructed, and installed bypassing all previously existing d.c. signal lines. In August 1976 this equipment was placed in full time service and operated continually until April 1978.

DISCUSSION

SYSTEM DESCRIPTION.

The technique, which Purdue devised, consisted of a new interface between the remote control and monitor stations located in the control tower and each ILS component facility in the field. In approaching the problem two steps were taken: signal processing and line protection. As the first step, signals *from the ILS field units* were processed and converted into a tone format for transmission to the central processing facility at the tower. There, the tones were reconverted into the original format necessary to drive the existing ILS remote control and monitor panels in the tower cab and equipment room. (This gave air traffic control (ATC) and maintenance personnel their familiar displays and control capability.) A stand-alone video terminal was included as part of the project to demonstarate the versatility of consolidated micro-computer-generated displays; this was located in the maintenance equipment room at the tower. Upon request, as entered from the keyboard, status and maintenance-monitor information could be displayed on the cathode-ray-tube (CRT). In addition, logged data could be recalled and control of the ILS effected via coded keyboard commands. Figure 2 shows the overall system concept. The status and control signals were picked up directly at the equipment terminals where they connect to the multipair cables. As a result, modification to any of the ILS equipment was unnecessary. The existing signal lines remained as a backup in the event that a failure of the Purdue equipment, during the evaluation period, would cause the loss of monitoring and control. As a convenient means of transferring between the system under test and the multipair d.c. system, quick-change plugs were provided at the tower and at each site. With this arrangement, each facility could be removed independently for testing or repairs.

At the individual sites, the ILS monitor and control signals exist as d.c.

voltages which are normally sent directly to the tower over leased telephone lines or buried cables, each signal being assigned to a separate line. In the Purdue system, however, these signals were conditioned, coded, and multiplexed using a microprocessor at the site yielding a string of binary bits representative of the cumulative status indications. The field unit that performed these functions is shown in figure 3. The bits, zeros and ones, were fed to a modem wherein they were converted into pairs of audio-frequency tones capable of being sent over a single pair of wires. (Of interest, here, is the fact that these same tones can be sent over a radio link to and from sites where running landlines would be impractical due to terrain or cost.) Through the judicious choice of tone-pair frequencies and filtering, bidirectional data communications were accomplished over the same pair of wires. In this way, only a single pair of wires is required for each facility. Voltage transients do not resemble the tone signals used and thus could not be misinterpreted as false cycle commands or indications, as was the case when using d.c. signaling.

In the second step, to protect the operating circuits from the effects of voltage transients on the lines, a balanced twisted-pair of wires was used in conjunction with center-tapped transfomers, one at each end (figure 4). (This is the same technique that telephone companies use for carrying voice and data with much success.) The transformers isolate the large induced voltages from sensitive circuits which are then safely diverted to ground through grounded center-taps. By their nature, balanced twisted-pairs cause any voltage surges to be applied equally to both lines with minimum transfer through the transformer. As a final precaution, gas-discharge arrestors were connected across the line, at each end, to short high-level transients to ground.

At the control tower, modems on each of the lines coming from the six field units converted the tones back into binary bits which were fed to a central microcomputer. Here the data were processed and formated for display on a CRT display (figure 5). Three types of information could be requested for viewing, the first being a "status" frame showing the status of each component of the ILS (figure 6). Next, a "maintenance-monitor" frame showed the status of the prealarm signals on the maintenance monitor (figure 7). The maintenance monitor is part of the CAT III ILS at NAFEC. The third type was a random access "log" programed to store selected data, including manual entries made from the keyboard (figure 8).

Control of the ILS units was accomplished in a similar manner as the remoting of the status signals. Upon closure of the "cycle" switch in the tower cab (or through coded keyboard commands), a control message was sent to the appropriate site, and the unit cycled main-off-standby as normally would be done.

As part of the demonstration, analog signals were remoted from the far-field monitor to both the tower and localizer. The three difference-in-depth-of-modulation (DDM) signals, normally relayed in analog form over the d.c. lines, were converted to digital form and processed in a fashion similar to the digitized status signals. After transmission, via the tone-signaling system, the digitized data were converted back into analog form for display as part of the maintenance-monitor frame on the tower CRT and on the front panel meter at the localizer.

EVALUATION.

Evaluation of the tone-signaling technique was conducted on the second generation equipment from August 1976 to April 1978 with all ILS facilities connected to it. The approach taken was to allow the system to run on a continuous, unattended basis and only make repairs when required. Periodic inspections were also made of the computer-maintained status and log entries to ensure the proper operation of the CRT displays.

All ILS facility or monitoring outages that occurred during this time period were reported by Eastern Region maintenance personnel to NAFEC project engineers. The NAFEC project personnel would then examine the tone-signaling equipment to ascertain if it was at fault. The nature of the failure and probable cause were determined and noted, and appropriate repairs were made to damaged components. As previously mentioned, it was a simple matter to reconnect the d.c. signal lines for an individual facility when necessary for making repairs.

RESULTS OF EVALUATION

During the test period, the ILS system exhibited satisfactory immunity to all forms of external interference; i.e., lightning and line transients except for the instances noted below. No false cycle commands nor erroneous status indications were observed in the course of normal operation.

The operating programs (software) for the field unit microprocessors and the central microcomputer at the tower performed flawlessly. The field units were operated from battery-supplied power sources and experienced no operational upsets. At the central microcomputer, only a long-term power interruption (one having a duration longer than several seconds) would require a manual reset. This problem could have been eliminated by the addition of an uninterruptable power source; i.e., one backed up with batteries as was done in the field units.

Failures in the Purdue equipment encountered over the test period were found to be due primarily to direct lightning strikes at the sites where voltage surges came in over the powerlines. Table 1 gives a listing of those failures recorded during the course of operations. In each case, the outage was localized to an individual site, and overall system operation was not affected. Components damaged were primarily semiconductor devices, integrated circuits, and resistors. The balanced-pair signaling lines and their associated modems showed no signs of damage from the strike. The worst instance occurred with the Purdue equipment at the far-field monitor, where improper installation of a lightning arresting device across the incoming powerlines was determined to be the cause. Extensive damage was also sustained by the far-field monitor circuits as well. Except for this case, operation of the ILS equipment remained unaffected by lightning/transients as a result of using the tone-signaling system.

TABLE 1. TABULATION OF FAILURES AND CAUSES IN PURDUE TONE EQUIPMENT OVER TEST PERIOD (INITIAL INSTALLATION--AUGUST 1976)

Date (1977)	Facility	Components and Circuitry Affected	Probable Cause	Remarks
Feb. 17	Far-Field Monitor and Middle Marker	Solid-State components in power supply, microprocessor, interface, analog/digital converter cards.	Direct lightning strike at site and improperly installed lightning arrestor on power lines.	Repaired by Purdue
Mar. 17	Outer Marker	(Overall Operation)	Lossy Lines	Repaired by Telephone Co.
Mar. 23	Middle Marker	(Overall Operation)	Noisy Lines-Hum due to water in Telco cables.	Repaired by Telco
Apr. 14	Localizer	Modem Integrated Circuit (MC6860)	Component Failure	
May 19	Central Processor	Interface Integrated Circuit (3404)	Lightning Strike at tower	
July 20	Localizer	Interconnect board printed circuit wiring for cycling control, burned up.	Lightning Strike at localizer site.	Voltage surge through ILS equipment
Aug. 14	Central Processor	Interface Integrated Circuit (3216)	Lightning strike at tower	
Sep. 15	Far-Field Monitor	Power Supply transistors (2-2N8066)	Component Failure	

A final report published by Purdue in two parts (references 5 and 6) gives further details on the second generation tone-signaling system as installed at NAFEC. Reference 5 reiterates the basics of signaling and line protection and explains the hardware used at the tower and in the field units. Operator information for the system is included as is a software listing for the field microprocessors. Reference 6 lists the program used by the central microcomputer servicing the tower displays and field units.

The system was observed by many technical groups during its operation at NAFEC. Because the equipment incorporated certain features incidental to its primary function of providing transient protection, it has proven useful as a model for current programs in remote maintenance monitoring that are expanding on its demonstrated capabilities. The evaluation showed that a microprocessor-controlled tone-signaling control and monitor system is indeed feasible for use to improve maintenance procedures and enhance remote equipment analysis. Some of the additional features which were demonstrated and show merit for incorporation in future systems include: analog to digital conversion of equipment parameters, automatic logging of these parameters and associated events for self-diagnosis and trend analysis, providing alarms and recording the times of significant operational changes, display of system data in a consolidated format on a video terminal, plus recall from memory and display of operating instructions and maintenance procedures. Such a system affords the capability of handling additional information, remoted from the field sites, to the degree of sensing device availability and funding. Disc or magnetic tape units for mass data accumulation as well as page printers for hard copy could easily have been added for long-term information storage and analysis.

CONCLUSIONS

From the results, it is concluded that:

1. The tone-signaling techniques used on the commissioned ILS at NAFEC proved to be highly reliable in meeting the needs of remote control and monitoring of a solid-state ILS while minimizing the effects caused by lightning/transients.

2. While no system can be immune to the effects of a direct lightning strike, a system of the type tested provides a high degree of protection from transient voltages induced in the control and monitoring lines.

RECOMMENDATIONS

It is recommended that:

1. In future ILS procurements, specifications state that monitor and control functions be performed using techniques similar to those reported herein (references 4 and 5).

2. Retrofit hardware be procured and installed at existing solid-state ILS facilities to increase system reliability and reduce leased telco costs, particularly at sites where lightning interference still poses a problem.

3. Microprocessor-controlled data communications be incorporated in the remote control and monitoring of all FAA facilities requiring constant attention, e.g., VOR, DME, and communication sites. The equipment and techniques being similar enough, the functions of various remote facilities could be handled by a single central processing unit.

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2. Huddleston, Gene K., FAA Lightning Protection Study: Circuit Modification for Mark III Instrument Landing System to Prevent Operational Upsets Due to Electrical Transients on Cables, Report No. FAA-RD-76-61, February 1976.

3. Bass, S. C., et al., Reliable Line Signaling Techniques for the FAA-GRN 27V and CAT-III ILS, Report No. FAA-RD-75-11, March 1975.

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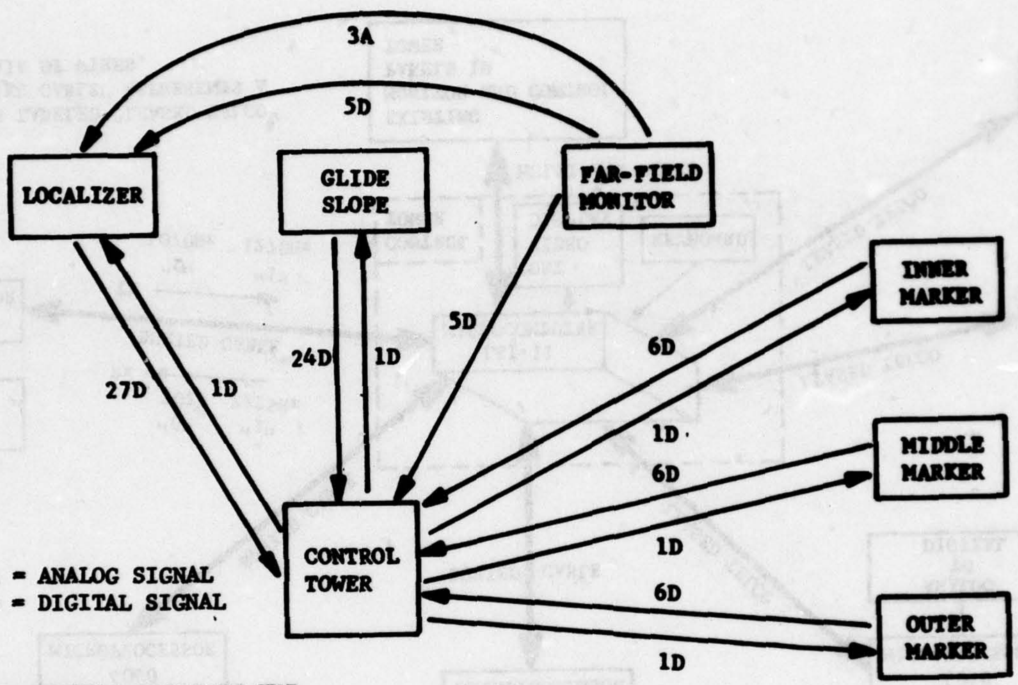
5. Belter, S. E., et al., Microprocessor-Controlled Communications In Air Terminal Navigation Systems, Report No. FAA-RD-78-25, January 1978.

6. Bass, S. C., Microcomputer Software for Advanced Instrument Landing System Communications System, Report No. FAA-RD-78-26, January 1978.



A = ANALOG SIGNAL
D = DIGITAL SIGNAL

NOTE: THE NUMBERS INDICATE THE NUMBER OF INDIVIDUAL SIGNALS FOR EACH FACILITY

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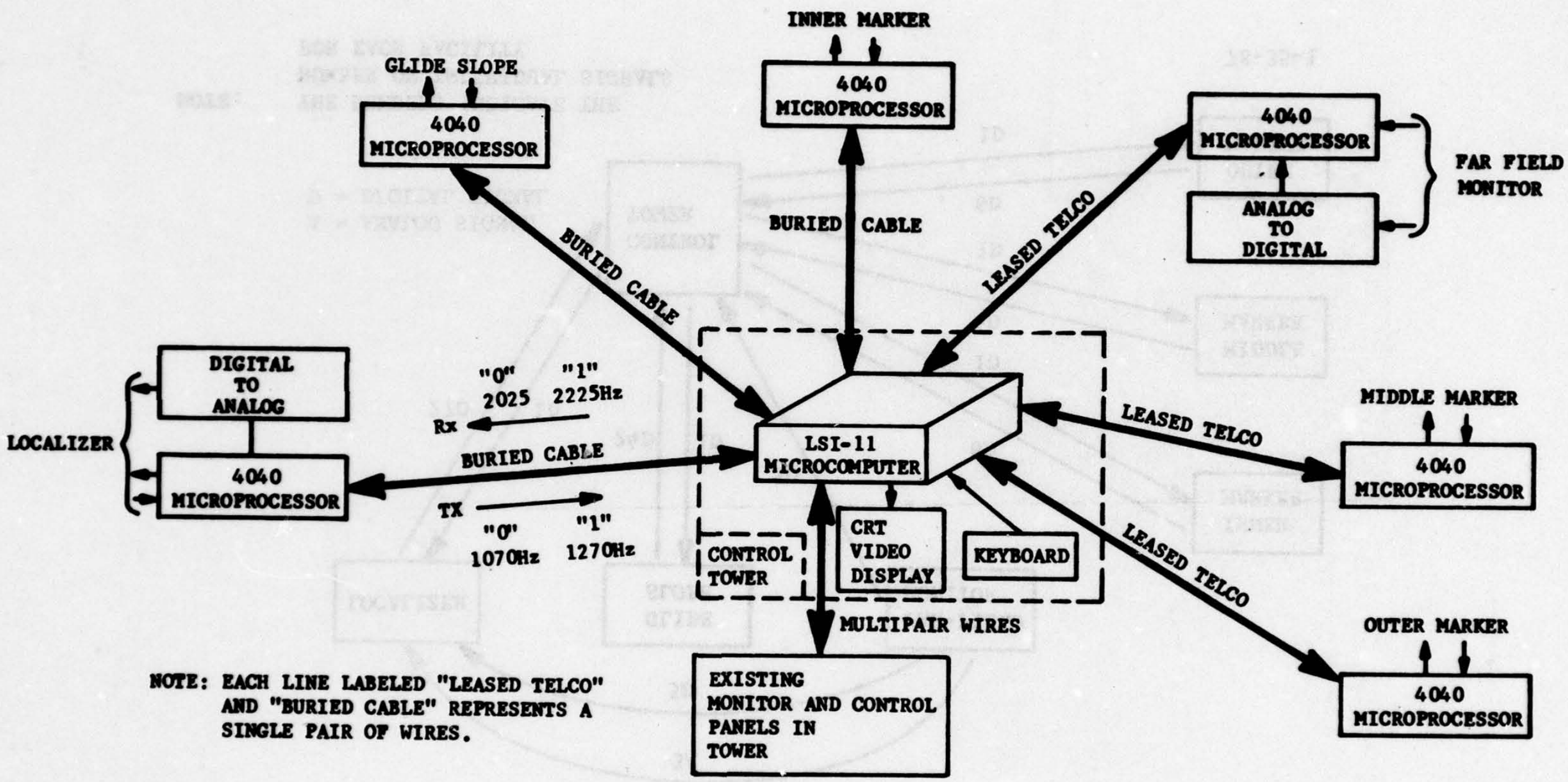
FIGURE 1. CAT III ILS SYSTEM INTERCONNECTIONS



NOTE: EACH LINE LABELED "LEASED TELCO" AND "BURIED CABLE" REPRESENTS A SINGLE PAIR OF WIRES.

FIGURE 2. MICROPROCESSOR-CONTROLLED DATA COMMUNICATION SYSTEM

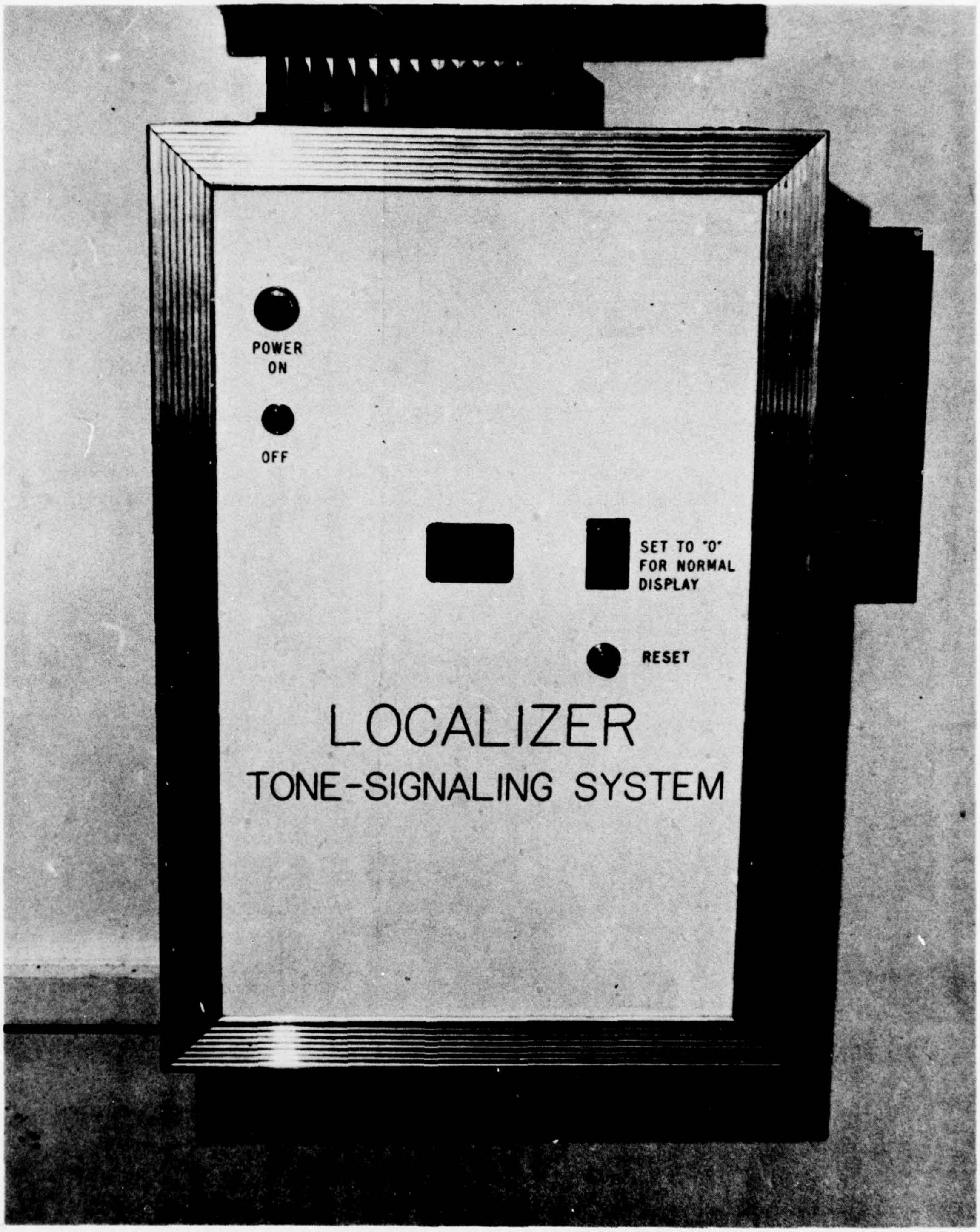

POWER
ON
OFF
SET TO "0"
FOR NORMAL
DISPLAY
RESET
LOCALIZER
TONE-SIGNALING SYSTEM

FIGURE 3

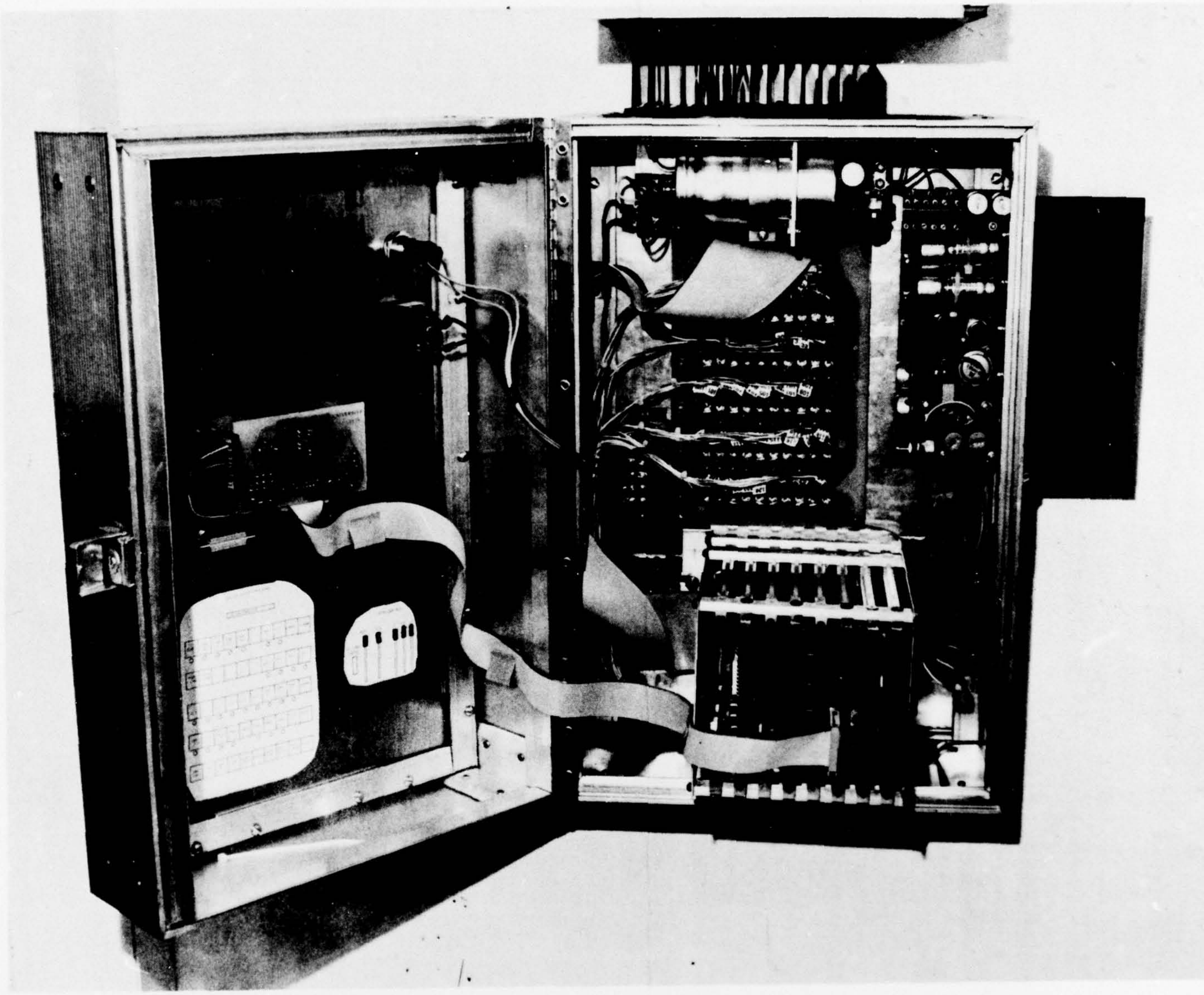


FIGURE 3. TYPICAL FIELD UNIT

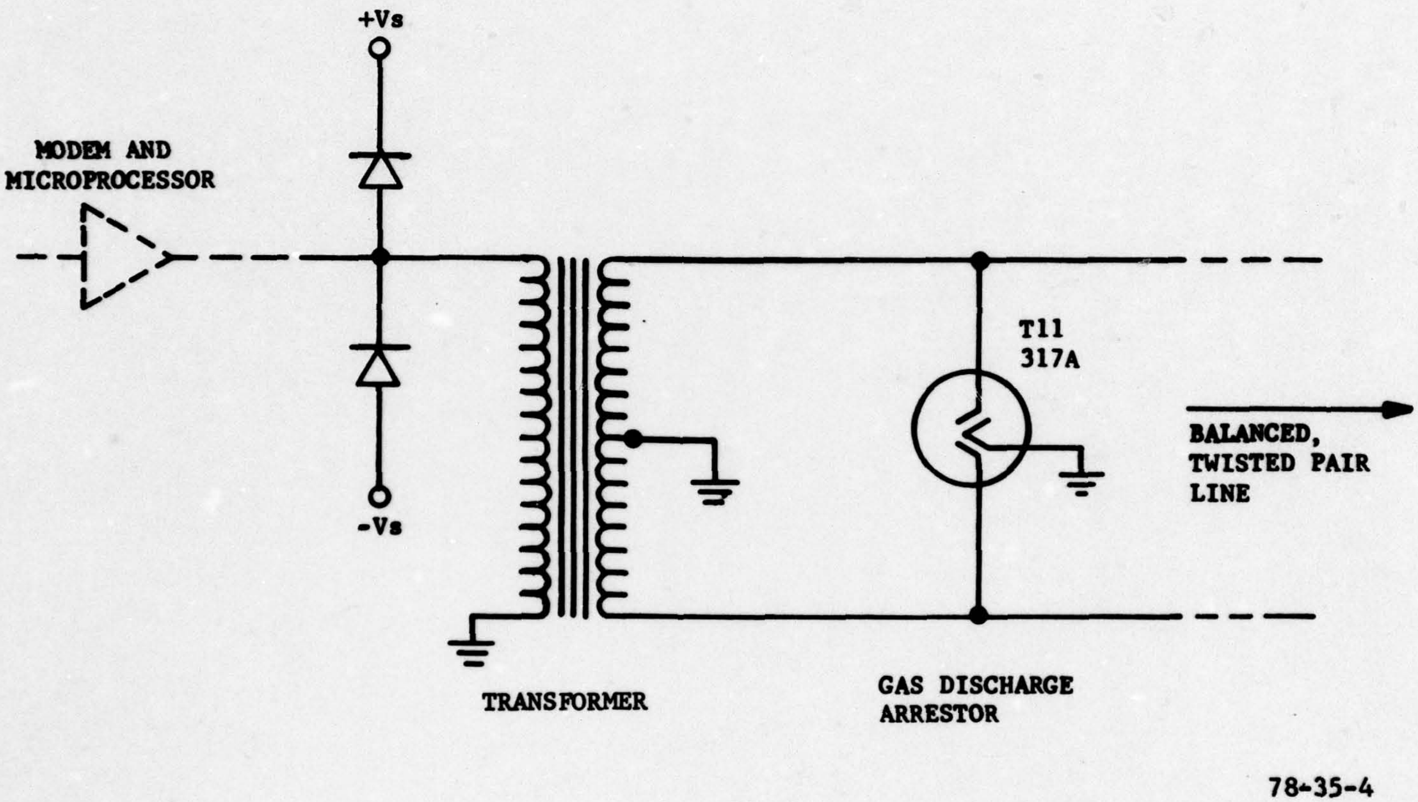


FIGURE 4. LINE PROTECTION TECHNIQUES

FIGURE 5. CENTRAL MICROCOMPUTER AND DISPLAY UNITS AT THE CONTROL TOWER

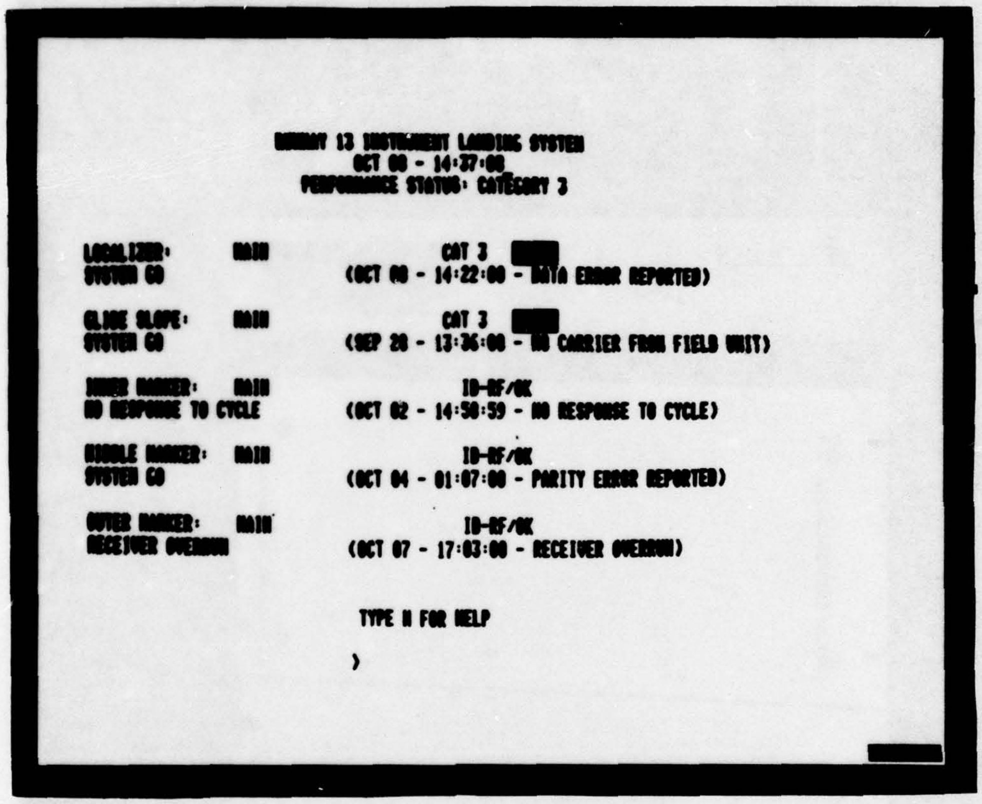


FIGURE 6. STATUS FRAME

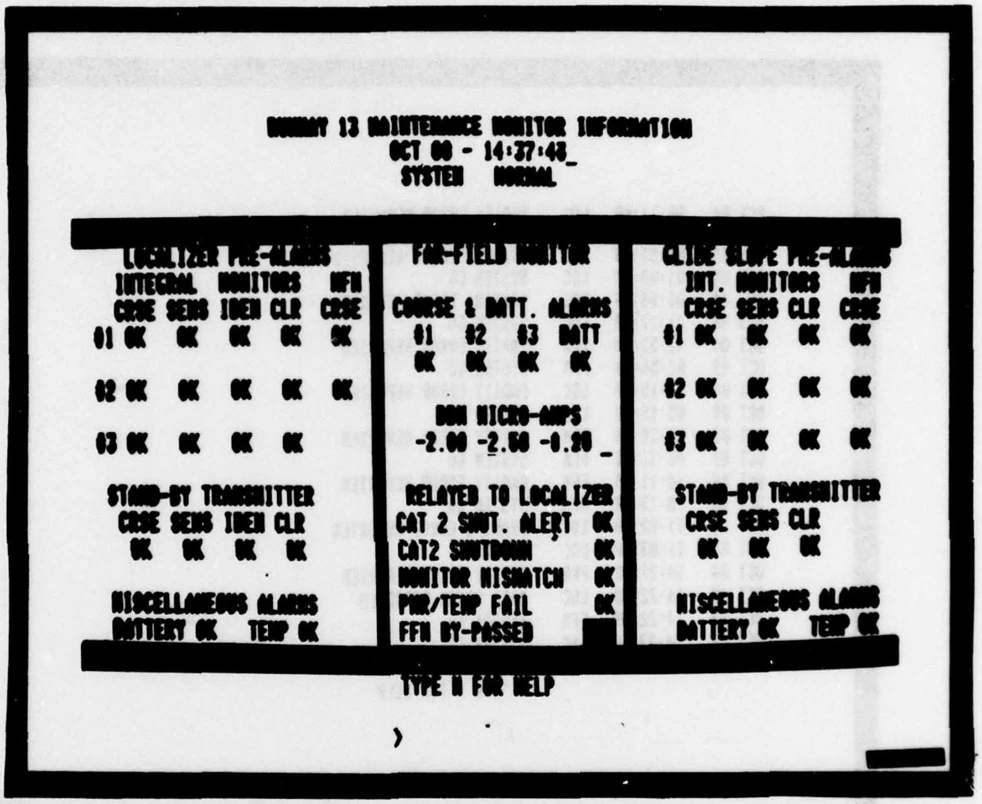


FIGURE 7. MAINTENANCE MONITOR FRAME

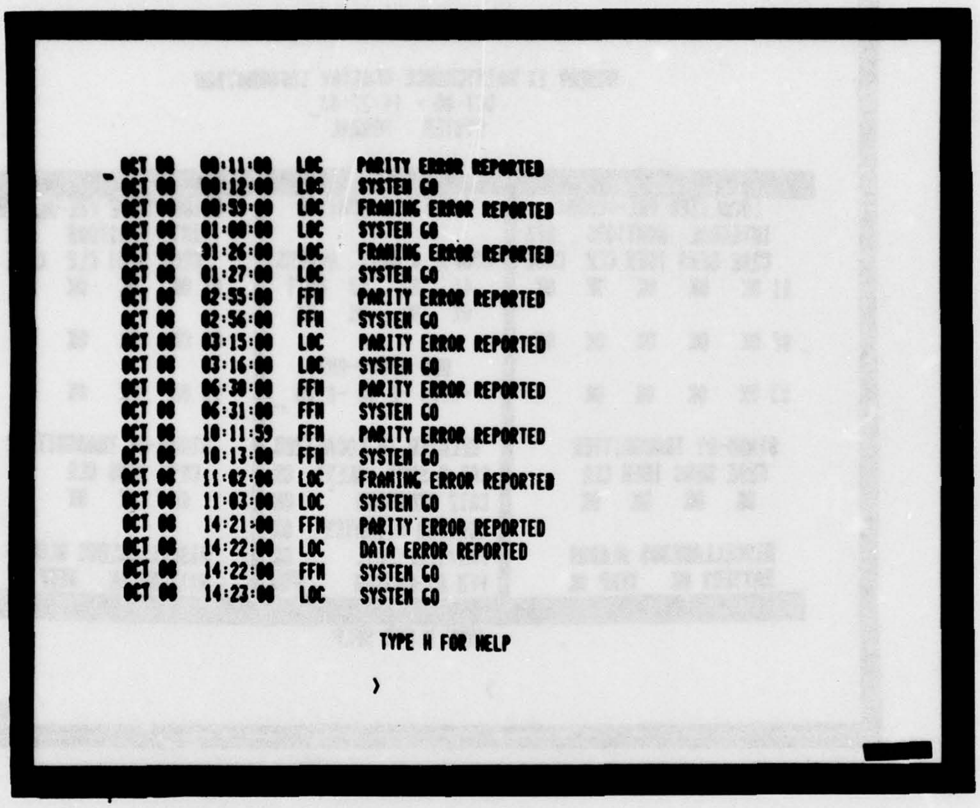


FIGURE 8. LOG FRAME